OVERVIEW of CASCADE SFA

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Co-Investigators

In partnership with Iowa State, Indiana University, UC Berkeley, and UC Davis

Travis O'Brien

Christina Patricola

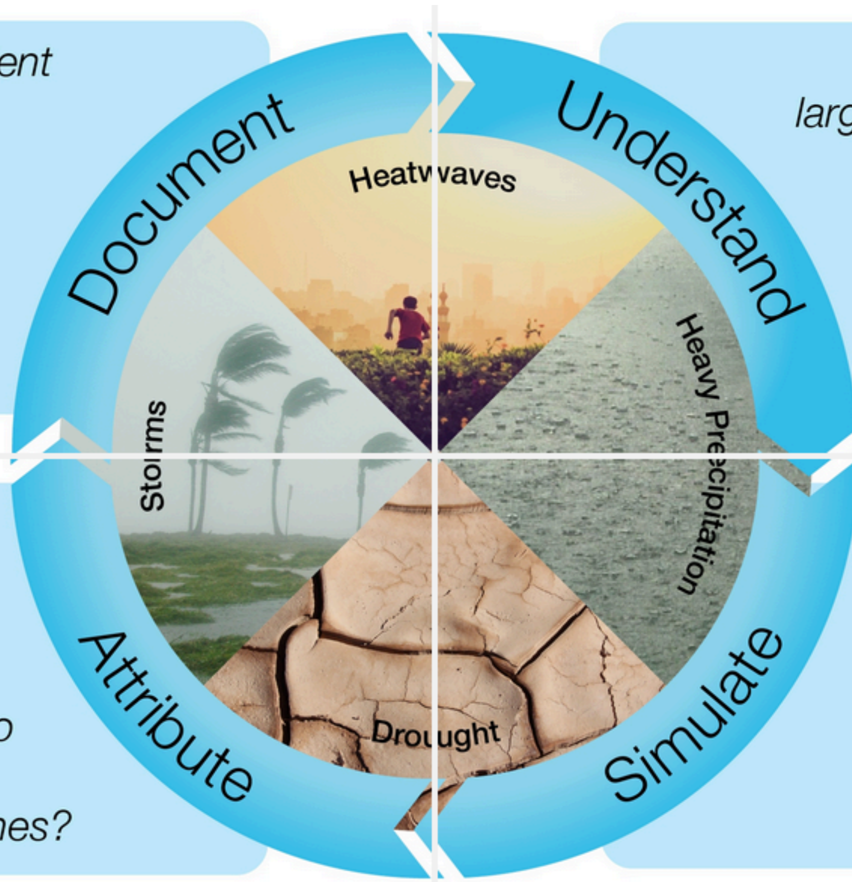
Mark Risser

Extremes: a WCRP Grand Challenge

World Climate Research Programme

Are existing observations sufficient to underpin the assessment of extremes?

What are the relative roles of large-scale, regional and local scale processes, as well as their interactions, for the formation of extremes?



What are the contributors to observed extreme events and to changes in the frequency and intensity of the observed extremes?

Are models able to reliably simulate extremes and their changes, and how can this be evaluated and improved?

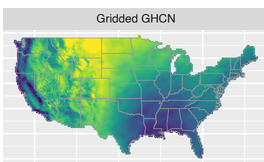
Source: www.wcrp-climate.org

CASCADE is designed to address these grand challenges

CAlibrated and Systematic Characterization, Attribution, and Detection of Extremes (CASCADE) SFA

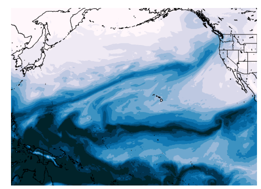
To advance understanding of natural and anthropogenic influences on multi-scale climate extremes in observations and models

Extremes in Observations



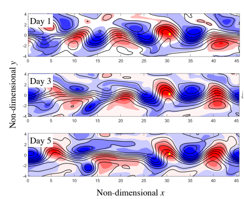
- Statistical modeling to interpret trends in the observational record
- Innovative geostatistical approaches for reducing signal-to-noise

Variability in Extremes



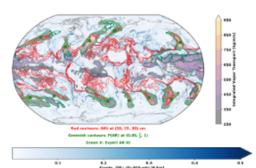
- Investigation of response of extremes to thresholds & non-linearities in the coupled system
- Emphasis on mountain hydroclimate

Extremes @ Native Scales



- High-resolution model & observational analysis of multiscale extremes
- Focus on MJO, blocking, teleconnections and model fidelity

Phenomenon-focused Evaluation of Extremes



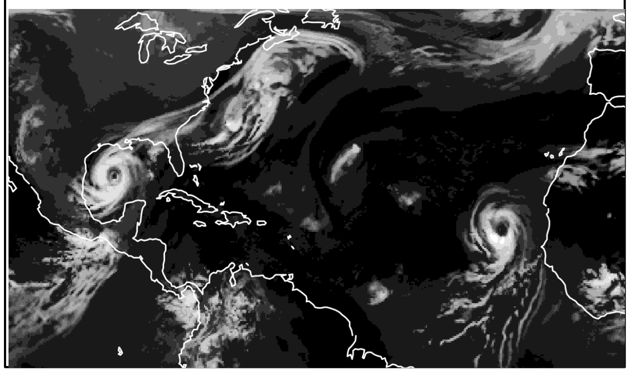
- Develop machine-learning approaches for detecting weather phenomena: ARs, TCs, ETCs, fronts,…
- Uses statistical and NN-based ML approaches

CASCADE Foci: Drivers and Responses of Key Extreme Phenomena

Tropical cyclones

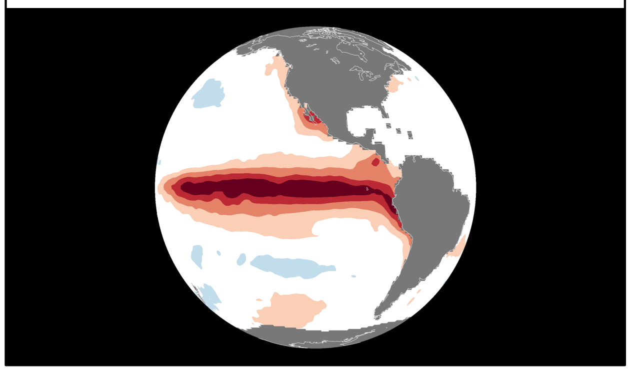
Large-scale drivers

Local and remote influences of variability and model biases



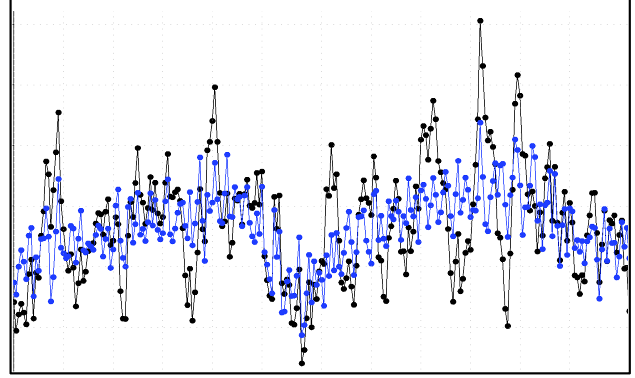
Oceanic drivers

Mechanisms connecting TCs and ENSO diversity



Weather-climate connections

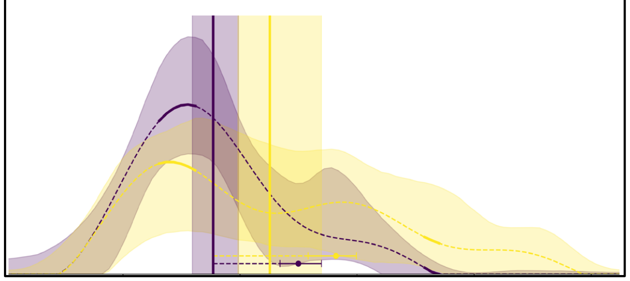
Typical TC precursor unnecessary to maintain TC climatology



Western US hydroclimate

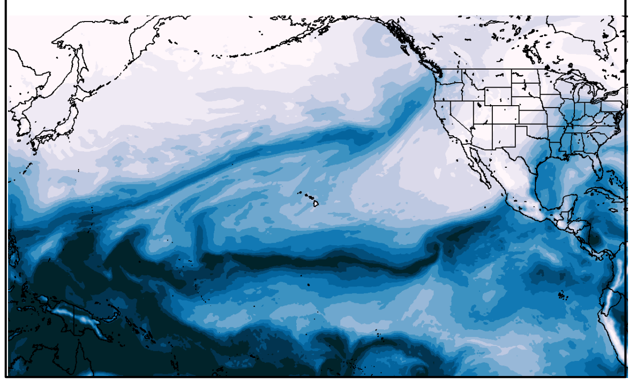
Large-scale drivers

Influence of modes of variability on co-occurring hydroclimate extremes



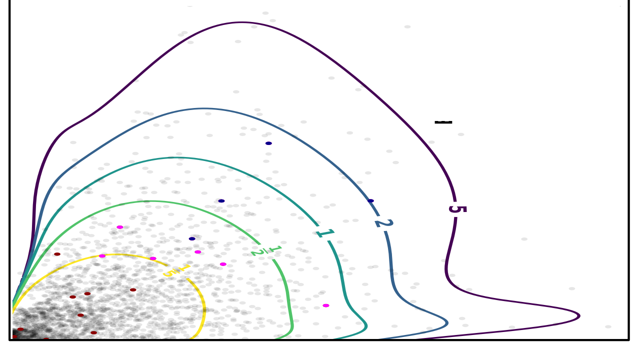
Oceanic drivers

Oceanic sources of Western US hydroclimate predictability



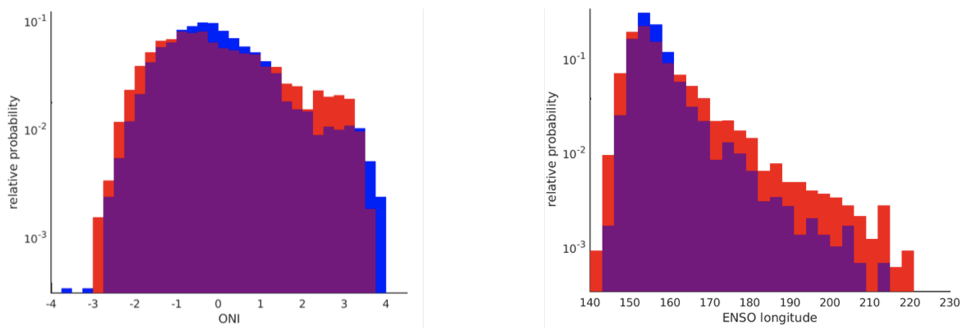
Weather-climate connections

Unusual clustering of precipitation events leads to seasonal extremes



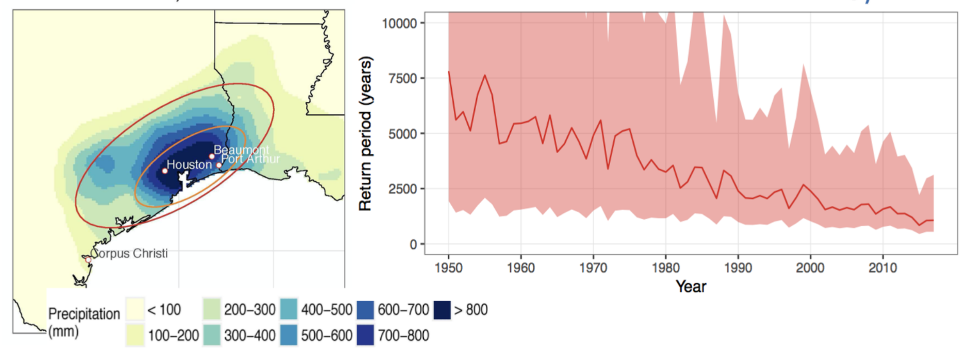
ENSO Teleconnections and Anthropogenic Impacts

Average longitude of tropical Pacific deep convection captures ENSO's diversity and teleconnections



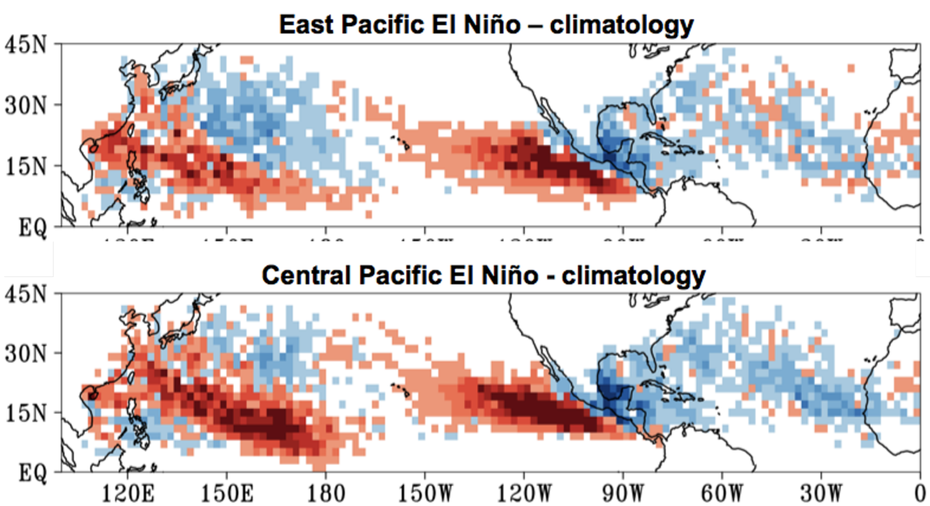
Williams, I.N. and Patricola, C.M. (2018), Diversity of ENSO Events Unified by Convective Threshold Sea Surface Temperature: A Nonlinear ENSO Index. *Geophysical Research Letters*, in review.

Attributable Human-Induced Changes in Extreme Precipitation during Hurricane Harvey



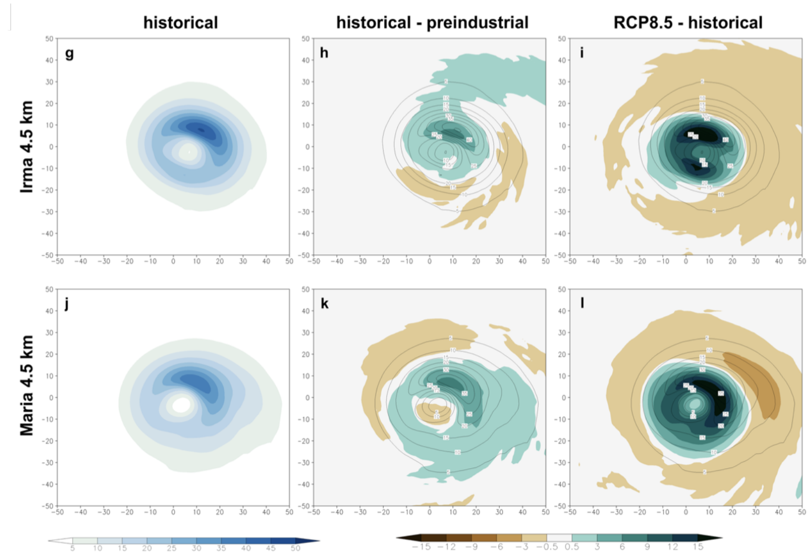
Risser, M., and M. Wehner, 2017, *Geophys. Res. Lett., 10.1002/2017GL075888*

Variations in El Niño's spatial patterns influence TC activity



Patricola, C.M., S.J. Camargo, P.J. Klotzbach, R. Saravanan, P. Chang (2018), The Influence of ENSO Flavors on Western North Pacific Tropical Cyclone Activity. *Journal of Climate*, 31, 5395-5416.

Anthropogenic Influences on the Intensity and Rainfall of Major Tropical Cyclone Events

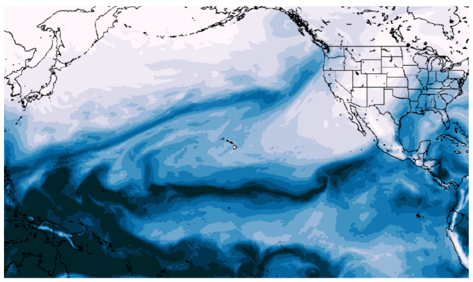


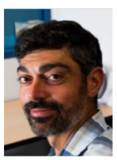
Patricola, C., and M. Wehner, 2018, *Nature*, in press.

Co-Occurring Extremes, Cyclogenesis, and Downpour Statistics

CASCADE

Understanding the physical drivers of co-occurring extremes



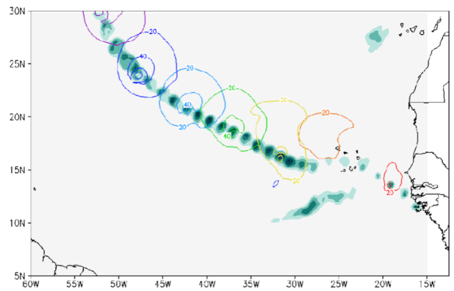


California temperature and precipitation extremes driven by atmospheric wave pattern
JP O'Brien et al. (2019)

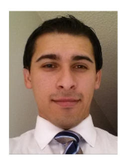
A collection of not-unusual storms can produce extremely wet seasons.
T. O'Brien et al. (2019)

Considering the spatial pattern of El Niño improves hydroclimate predictability.
Patricola et al. (2019)

Modeling the connections between tropical cyclone precursor and frequency

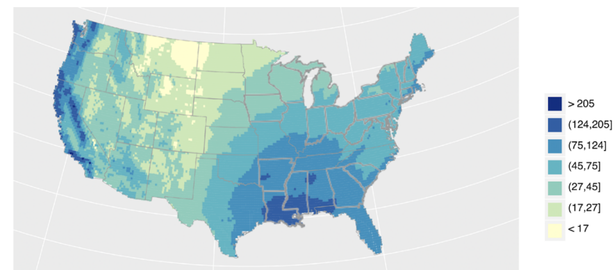


Mechanistic climate model experiments reveal Atlantic hurricanes are not limited by their typical precursor.
Patricola et al. (2018)



Developed statistical model of tropical cyclone genesis that quantifies the changing importance of predictors in a warming climate.
Fernandez et al. (2019)

Quantifying uncertainty in observed and simulated precipitation extremes



Precipitation extremes are different among gridded observation products.
Timmermans et al. (2019)

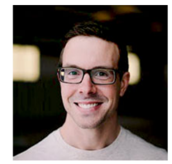
Created an extreme precipitation climatology using extreme value analysis.
Risser et al. (2019)

Scaling formulas can approximate extreme rain in superparameterized CAM.
Fildier et al. (2018)

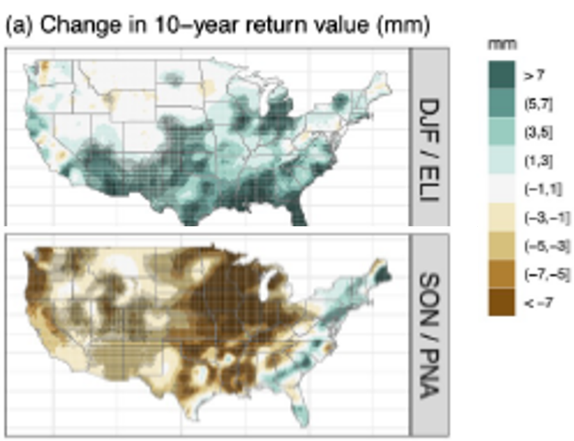
New Analytical Methods for Observational and Model Data

Creating new observational datasets and software using advanced statistical methods to enable research on extreme weather/climate events



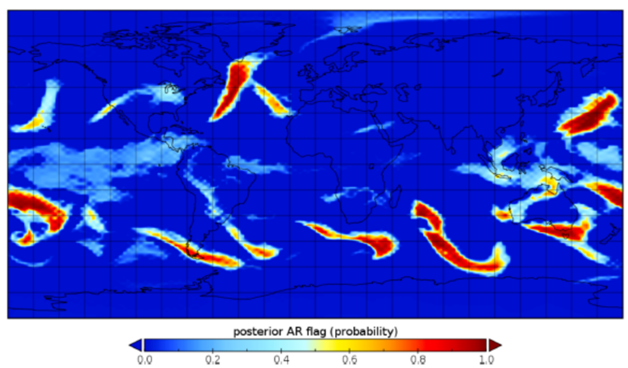



Developing most accurate statistical models to characterize extreme weather and precipitation



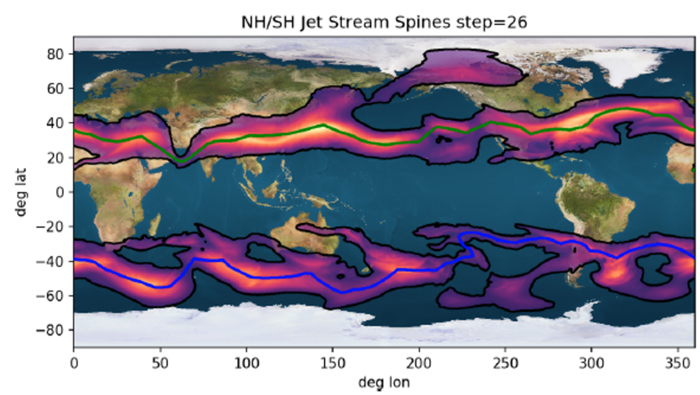
- Risser et al. 2020
- Paciorek et al. in prep

Detecting atmospheric rivers and quantifying uncertainty using machine learning and Bayesian statistics



- O'Brien et al. 2020

Implementing a new jet stream detector in TECA

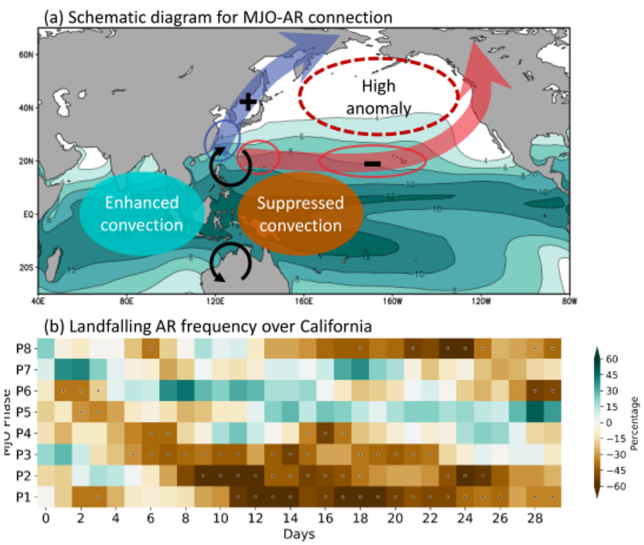


https://teca.readthedocs.io

Impacts of Internal Variability: MJO, ENSO, AEWs, and Blocking

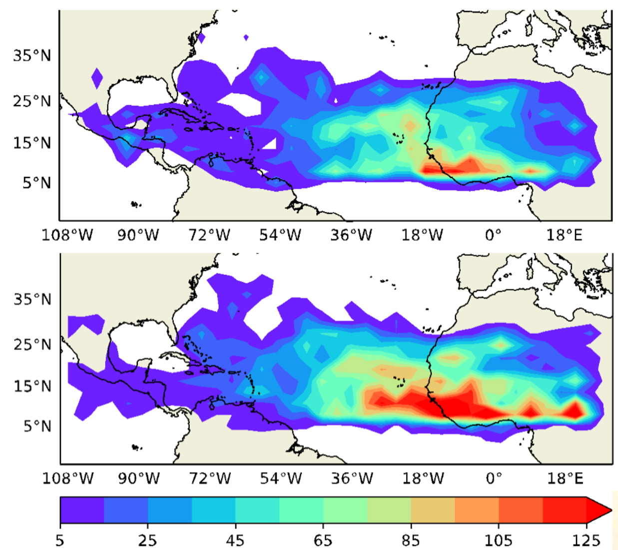
Understanding how multi-scale processes, coupled feedbacks, and non-linearities in the Earth system influence extreme weather/climate events

Improving seasonal prediction and future projection of atmospheric rivers and hydroclimate: climate change, MJO, ENSO



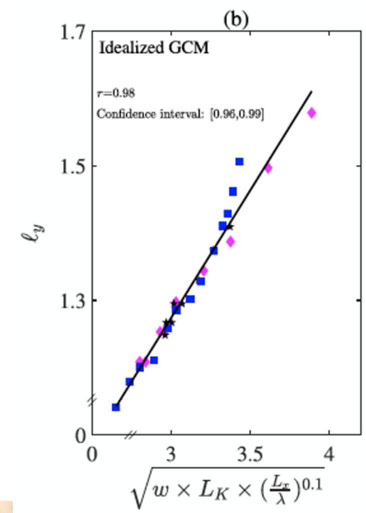
- Rhoades et al. 2020a and b
- Patricola et al. 2019
- Zhou and Kim 2019

Drivers of variability and change in tropical cyclones: ocean temperature patterns and tropical cyclone precursors

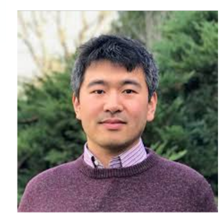


- Bercos-Hickey et al. in prep
- Lin et al. 2020
- Balaguru et al. 2020

Processes that govern extreme precipitation and drought-inducing atmospheric blocking

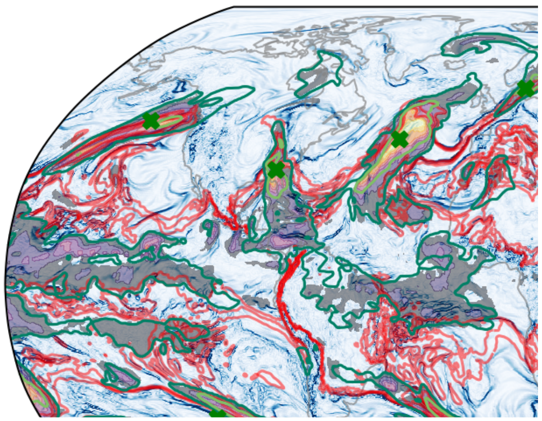


- Charn et al. 2019
- Huang et al. 2020
- Molter et al. 2020
- Nabizadeh et al. 2019



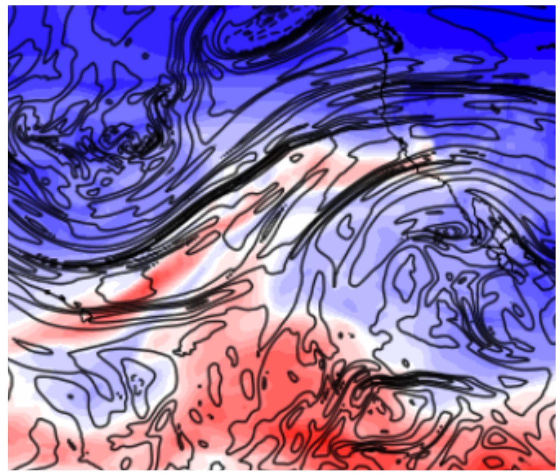
Multiple Complementary Approaches for Feature Tracking

Three complementary approaches:
- A UQ testbed
- A 1st principles testbed
- An ability to emulate the two – computational efficiency



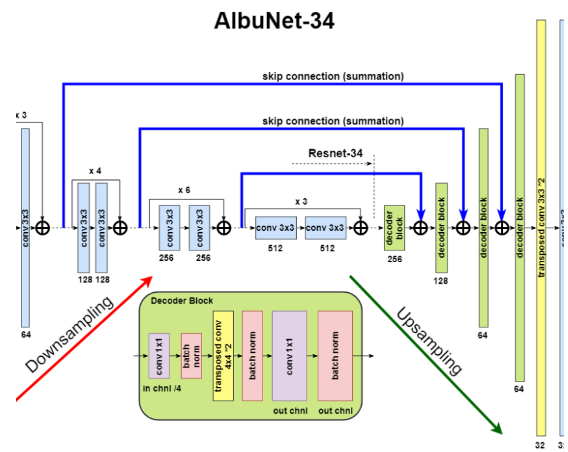
Probabilistic Heuristics

Bayesian



Finite Time Lyapunov Exponents

Lagrangian



Convolutional Neural Networks

Machine Learning

Toolkit for Extreme Climate Analysis – TECA3

build passing docs passing

TECA

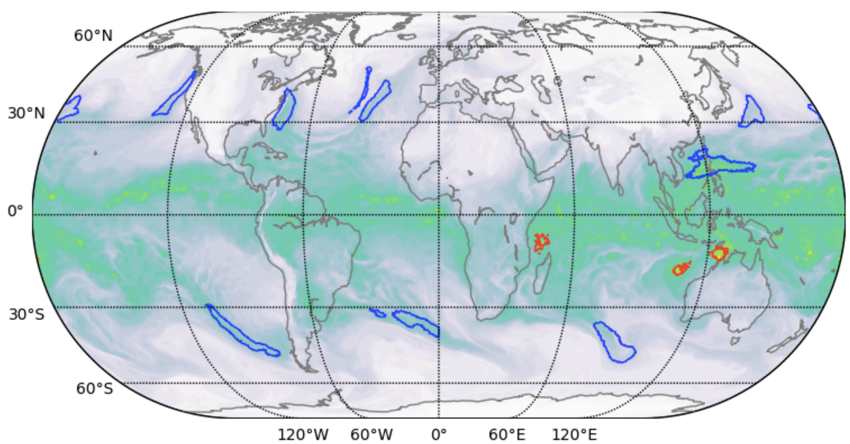
`pip install teca`

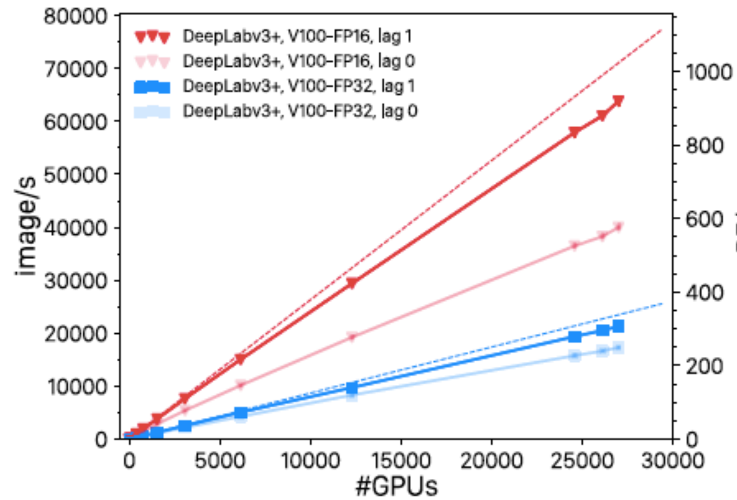
- Implementation of advanced phenomenon detectors
- User engagement: TECA tutorials
- Integration with Coordinated Model Evaluation Capabilities (CMEC)

Current TECA Detectors
Tropical Cyclone (GFDL algorithm)
Bayesian AR Detector
Planned TECA Detectors (CASCADE3)
Machine Learning AR Detector
Bayesian TC Detector
Machine Learning TC Detector
Bayesian AEW Detector
FTLE-based AR Detector
Planned TECA Detectors (CASCADE4)
Bayesian & ML ETC Detectors
Bayesian & ML Front Detectors
Bayesian & ML MCS Detectors
Blocking Detectors

2018 Gordon Bell Award for first Exa-Op Climate Application

Exascale Deep Learning for Climate Analytics





Ankur Mahesh

- Deep Learning application scaled to whole ORNL LCF system
  - Strong scaling to 4,560 Summit nodes (27,360 Volta GPUs)
  - 1.13 Exa-ops/s peak
  - 0.99 Exa-ops/s sustained
  - 90% scaling efficiency

- Team: Thorsten Kurth, Sean Treichler, Joshua Romero, Mayur Mudigonda, Nathan Luehr, Everett Phillips, Ankur Mahesh, Michael Matheson, Jack Deslippe, Massimiliano Fatica, Prabhat, Michael Houston. **NERSC, NVIDIA, OLCF**

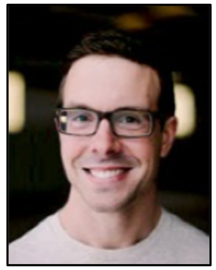
CASCADE's Presentations at this RGMA PI Meeting

Speaker	Title	Time Slot
Yang	Amplified Madden–Julian oscillation impacts in the Pacific–North America region	Tuesday 1.4 1:47 PM
Patricola	Future Changes in the Relationship Between Tropical Cyclones and ENSO	Tuesday 1.3 2:55 PM
Huang	Sources of subseasonal-to-seasonal predictability of atmospheric rivers and precipitation in the western United States	Tuesday 1.5 4:00 PM
Zhou	Uncertainties in Atmospheric River Life Cycles by Detection Algorithms	Tuesday 1.4 4:28 PM
Molter	Quantitative Precipitation Estimation of Extremes over the Continental United States with Radar Data	Wednesday 2.1 1:40 PM
Wehner	Evaluation of extreme subdaily precipitation in high-resolution global climate model simulations	Wednesday 2.1 1:45 PM
Risser	Quantifying the influence of natural climate variability on in situ measurements of seasonal total and extreme daily precipitation	Wednesday 2.1 1:50 PM
Mahesh	Probabilistic Detection of Atmospheric Rivers Across Climate Datasets and Resolutions with Neural Networks	Wednesday 2.1 1:55 PM
Rhoades	The Shifting Scales of Western US Landfalling Atmospheric Rivers Under Climate Change	Wednesday 2.1 2:45 PM
Bercos-Hickey	Anthropogenic Influences on African Easterly Waves	Wednesday 2.3 2:54 PM
Collins	HighResMIP, in CMIP6 Hackathon	Thursday 1:30 PM
Collins	Artificial Intelligence / Machine Learning Panel	Friday 12 PM

Thanks to the CASCADE Team. Questions?

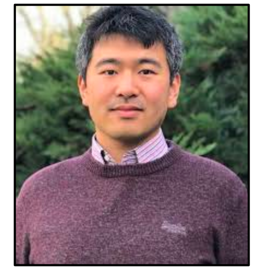

Collins


Patricola


Risser


O'Brien


Boos


Yang


Wehner


Cholia


Elbashandy


Keen


Loring


Paciorek


Sopher


Bercos-Hickey


Charn


Inda Diaz


Huang


Mahesh


Molter


Rhoades


Zhou